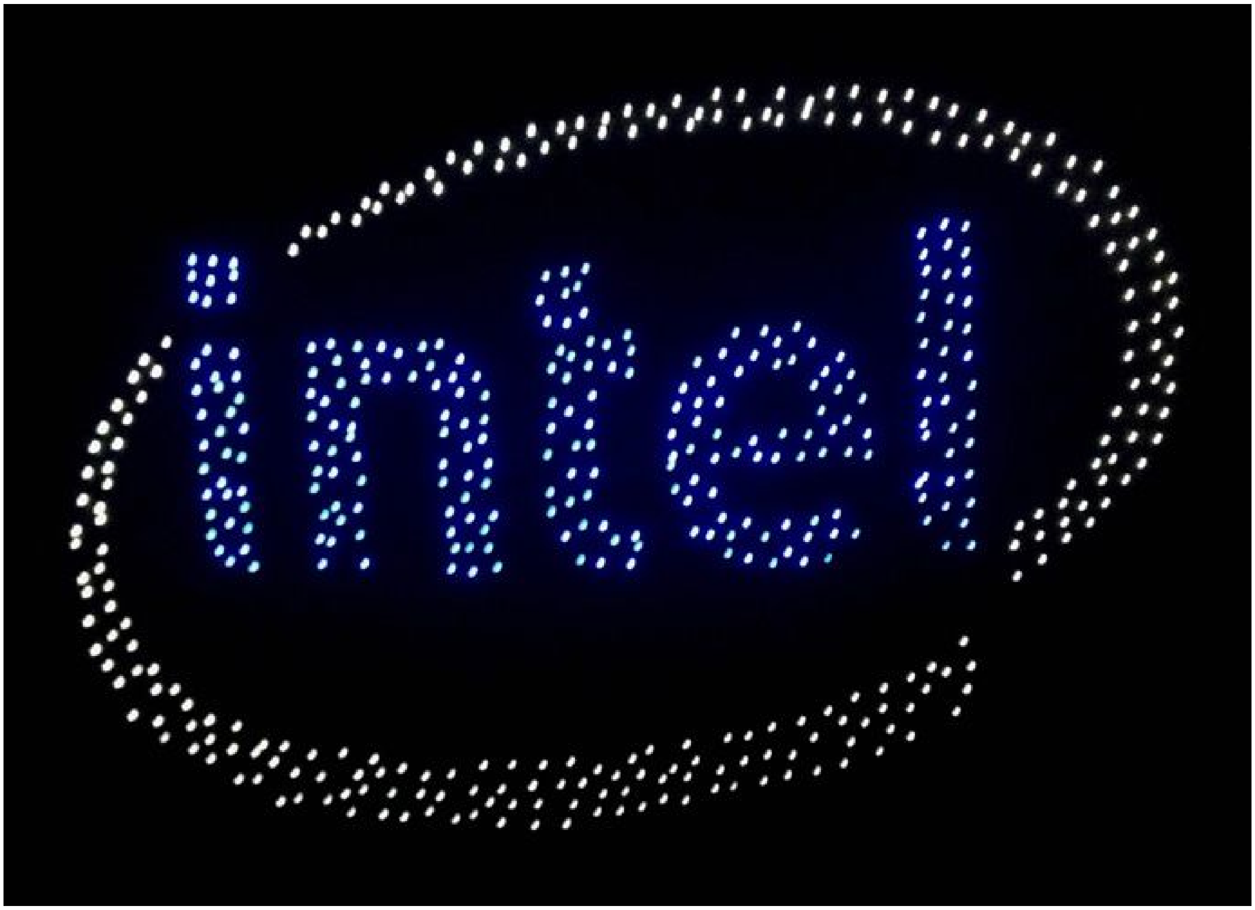
Drone Clusters as Sky Light Displays

Team 7409



Summary:

Technology is allowing for more and more fascinating displays and shows. As time has continued, these new developments in technology have further modernized the entertainment industry. One example of this modernization is drone technology. On top of drones having military, recreational, and surveillance uses, entertainment is another industry where drones have potential uses. Drone Clusters as Sky Light Displays explores the potential of drones as an entertainment method.

To determine whether the aerial light show could be performed, we found the optimal requirements for the air show. To find the required launch area, we found the maximum park size of a "large city," assuming that it was in the United States. Then, we were able to find the predicted population of the viewers, and we subtracted the projected area that they would take from the total area of the park.

We also considered safety measures by creating a plane at an angle (θ = 2.87°), which was calculated by finding the optimal angle that people enjoy watching fireworks. Many studies have shown that 30° is the optimal angle for light show viewing, and we used this to our advantage to create a plane that was perpendicular to the 30° optimal viewing angle. This plane represented the 2 dimensional area (the required area space) where the drones would travel. We found the volume under this area, and set precautionary restrictions as to where the viewers could stand.

Our three displays consisted of a ferris wheel, a dragon, and a rocket ship. In the first part of the show, we determined that the easiest way to launch the drones was to set the drones in "ferris wheel formation," where the entire image would be rotated at an angle of 60°. This would not only be the safest method, but also the most time efficient method.

To find the number of drones that we needed for an image, we found that the Intel recommended distance between drones needed to be at least 5 ft (1.524 m). However, there needed to be enough drones so that the image was visible to everyone in the audience.

We must not neglect the fact that the drones running in such a small area have a large likelihood of hitting each other. In order to avoid these hits the drones were designated to move on different planes depending on their necessity and destination. For example, unnecessary drones move far from the image and then fly downward to avoid hitting other moving drones. The drones are designated to fly through the air.

The drones would be nice for the town because it allows for more freedom with the presentation as well as demonstrates technological advancements, provides entertainment, and is a safe opportunity for the people. The aerial light show is a wonderful chance to allow the town to explore new technology.

To: Mayor

From: Team 7409

Drone Cluster Light Show

Overview

The Drone Cluster Light Show is an excellent opportunity to showcase the modern technology of the city with a beautiful display. The light show would be put on using around 650 drones. These drones would be flown in different locations to create images that would be recognizable by the people. The show would produce a ferris wheel, dragon, and a rocket ship.

Safety

The area required to be set aside for safety is 0.01225km. If park is square and about 0.045 in side length, the other length of the danger is about 0.025km. This area a small fraction of the total area meaning it would be easy to put on without putting anybody in danger. However, by using the drones there is a small likelihood of an accident, but by putting the festival on a good weather day, it is possible to dramatically increase safety.

Shapes

The light show would produce three images: a ferris wheel, a dragon, and a rocket ship. These shapes vary in complexity causing the spectators to see both complex and simple actions by the drones. The dragon, the most complex image, requires many different points to illustrate the many details of the dragon. The ferris wheel shows the drones rotating which would demonstrate a circular pattern, a more simple design. The final image would be a rocket. The image would highlight the scientific advances in technology and would blast us off into the future.

Transformations

The first animation would be the ferris wheel. It would be animated using a rotation that would rotate the wheel part of the image. However, the frame of the ferris wheel would not be animated and would not rotate at all. The dragon would have a rotation as well. The wing of the dragon would be rotated 20 degrees counter clockwise. This creates the illusion of the dragon flapping its wings. The rocket ship would be translated up. This would give the illusion of the rocket flying away for the grand finale of the show.

Drones in Flight

The drones would have to fly from their points to perform the translation one danger would be the drones crashing. However, by implementing a computer program, it is possible to have them move without hitting each other. Points in high concentration areas that are not needed for the third image will be moved back and away from the image to allow for them to not interfere with the rest of the drones.

Conclusion

The drones would be an excellent choice because they demonstrate the modernization of science, they are safe, and they would be fantastic show to watch. By utilizing this new technology, the city exemplifies itself as being modern and a part of the future. The drones are safe with only a small area under their fall and a lack of wind would prevent them from moving.

Problem Restatement:

The problem is to create a sky show using a cluster of Intel Shooting Star Drones. Our objective is to mathematically simulate the flight paths of individual drones, and use statistics to find the number of drones needed for the sky show. We also had to create a two-page memo to summarize the results of our investigation.

Assumptions and Variables:

- The location is in the United States
- The population of the city is about 530,000 people
- The size of the largest park is about 50 acres
- The max height between the drone and the ground is 121.92 m.
- The average weight of a drone is 330 g
- The battery life of the drone is 20 minutes
- The maximum speed of a drone is 3 m/s
- The dimensions of the drone are 382 mm by 382 mm by 83 mm
- Max range from the control to the drone is 1500 m
- The drones cannot legally fly above 91.44 m vertically
- Viewers will view the light show at a 30° angle above the horizontal
- The park is square

Hypothesis:

With all the safety and launch area concerns taken into consideration, the aerial lights show would be a beneficial and noteworthy addition to the festival.

Model:

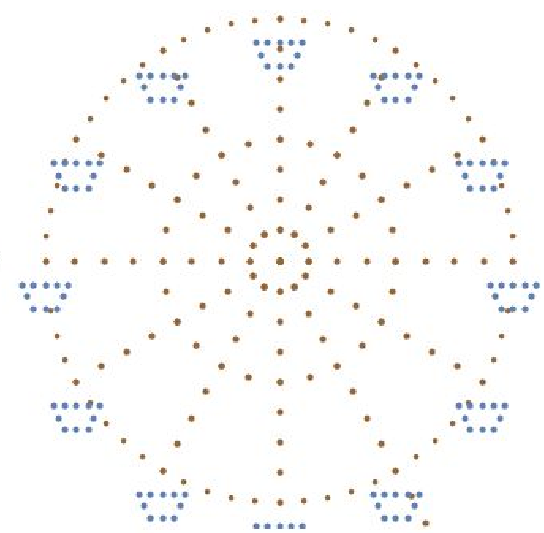
Part I:

NOTE: Points in graphs represent individual drones. Point colors in model graphs do not necessarily represent the real colors of the drones during the light show. Also, the points are not necessarily at the

Before the show, the drones need to be arranged in a 2 dimensional image on the ground. This image will be distorted, but will allow for the drones to easily fly into the air. Since the drones cannot be within 1.524 m of each other, they can be in the ferris wheel formation.

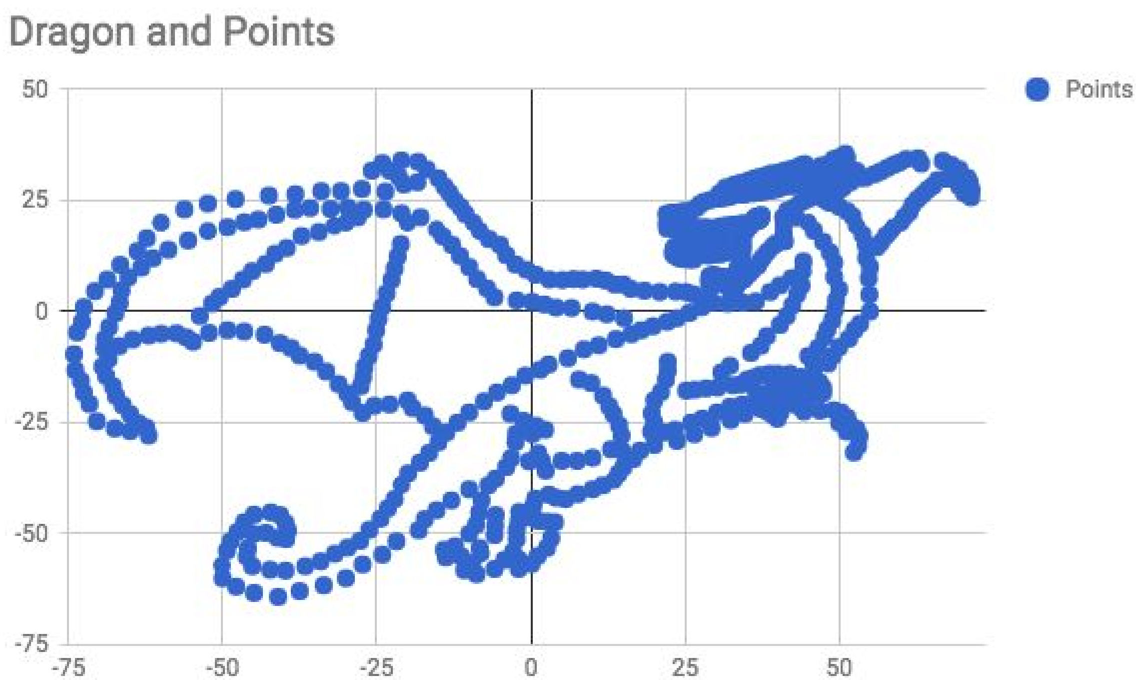
Ferris Wheel

The first shape that we created was the ferris wheel. The drones were arranged into two circles with lines running different radii every 30°. We started by creating the points of the outer circle. We then calculated the slopes of all of the individual lines and found the individual points that would make the different spoke lines on the ferris wheel starting from the center. After finding these individual points,, we plotted those and created two more circles on the interior of the ferris wheel, both with radii such that the points on the ferris wheel aligned with the points on the new circles. This resulted in the ferris wheel having the interior circles and the 12 spokes. Then, the ferris wheel cars were made by finding sets of points below the intersections of the spokes and the largest circle. For the actual animation of the ferris wheel, we decided that the ferris wheel would turn at a rate of 2 degrees every ¼ second, because this is the angular velocity of a real ferris wheel. Every ¼ second, the point (x,y) on the ferris wheel gets transformed to the point (cos(2)*x+sin(2)*y, -sin(2)*x+cos(2)*y) . Therefore, as time goes on, the ferris wheel makes a rotating motion on its center point. To find where the cars of the ferris wheel go, we found where the the intersection points of the ferris wheel and the cars get transformed to, and then we used the same method as before. We found the set of points directly below the intersections and plotted those. This resulted in the cars staying upright but moving position, while the ferris wheel itself rotated about the center point.



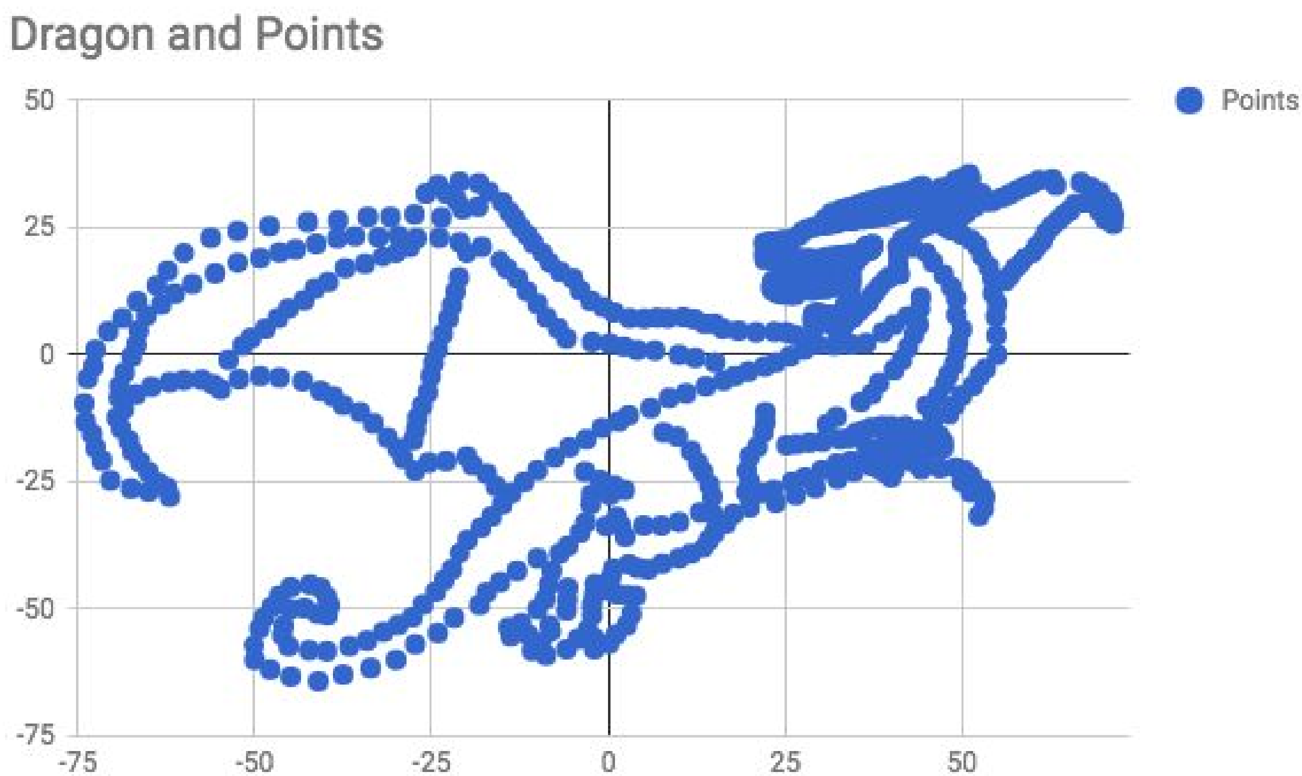
Dragon

The dragon was a bit more difficult. In order to animate the dragon, we decided to transform the wing to give an illusion of flight. The wing would rotate, giving the illusion that the dragon was flying.



Original dragon image

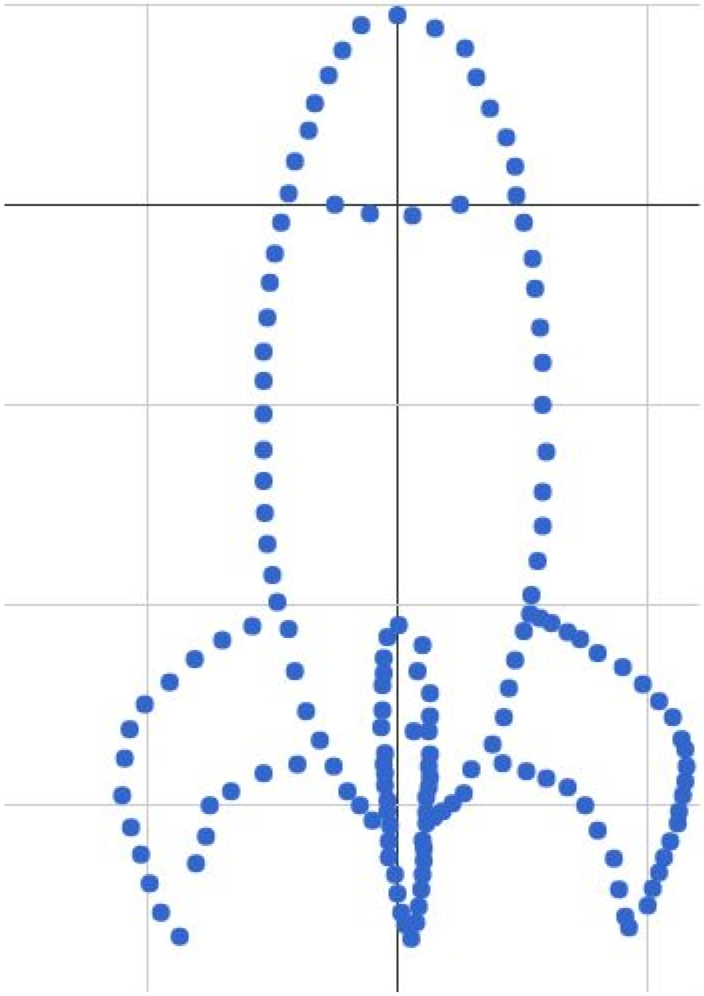
The translated dragon rotates the dragon wings 20 degrees counterclockwise. We found that the x-coordinates of the points of the wing would end up at cos(-20)*x+sin(-20)*y, and the y coordinates would end at -sin(-20)*x+cos(-20)*y. In order to get a "smooth" animation, the points on the wings would have to be put under repeated transformations to make up for the multiple frames of the animation. The normal rate of animation motion is generally 12 frames per second. Because we were rotating the wing of the dragon by 20 degrees, and the total amount of time that the animation is displayed is approximately 60s, there would be 720 frames overall. We also decided that 15 flaps from the dragon wing would be an optimal number of flaps given the amount of time that the dragon is shown. Therefore, there would be approximately 48 frames per transformation and 4 seconds per flap. Since the rotation goes through 40 degrees in 48 frames, there will be $\frac{5}{6}$ degrees per frame. Also, the frames will change every 4/48=1/12 seconds. Therefore, every 1/12 seconds, every point (x,y) on the dragon wing will be translated to (cos(-5/6)*x+sin(-5/6)*y, -sin(-5/6)*x+cos(-5/6)*y) until the wing has rotated 20 degrees, and then after 2 seconds, every point (x,y) goes to(cos(5/6)*x+sin(5/6)*y, -sin(5/6)*x+cos(5/6)*y). This will result in a rotation fast enough such that the viewers will be able to see a clear animation of a dragon flapping its wings, while being slow enough such that the drones can keep to speed.



Dragon with fully rotated wing

Rocket Ship

The final image is the rocket. The rocket was made in a similar way as the dragon, with points overlaid on an image of a rocket ship. We spaced out the drones such that the drone area would not be too crowded, but at the same time the rocket was clearly distinguishable. For the animation of the rocket, we decided to use a simple translation upwards. A drone would translate from a point (x,y) to a point (x+⅙,y+⅙) every ½ second. This ensures that the rocket moves up at a fast enough rate that the would be interesting to the viewers, but at the same time not too fast that the viewers would miss the experience. The rocket starts all the way at the ground and goes to the top of the legal height limit in 20 seconds.



It is important to note that these scales would not be used for the actual image and would need adjustments for the actual show.

Part 2:

To find the flight paths of each drone, a diagram of the situation is needed. First, the population of the "large city" needed to be found. We did this by taking the definition of a "large city," taken from *Ekistics: an introduction to the science of human settlements [Hutchinson, 1968]*, which stated that the population of a "large city" is between 300,000 and 1,000,000 people. We assumed that the location of the light show was in the United States. We found all of the cities with a population of 300,000 to 1,000,000. The average of the 54 these cities was taken and determined that the population of a large city is, on average, 530,000 people (See Appendix A). Using the average, we compared a city of that size to a similar city, Boston and used its largest park's area, the Boston Common.

The distance between the individual drones and the control system cannot exceed 1500 m, according to the Intel News Fact Sheet. This means that a hemisphere can be drawn from the control system to the max range of a drone. This diagram is depicted in Figure 1.

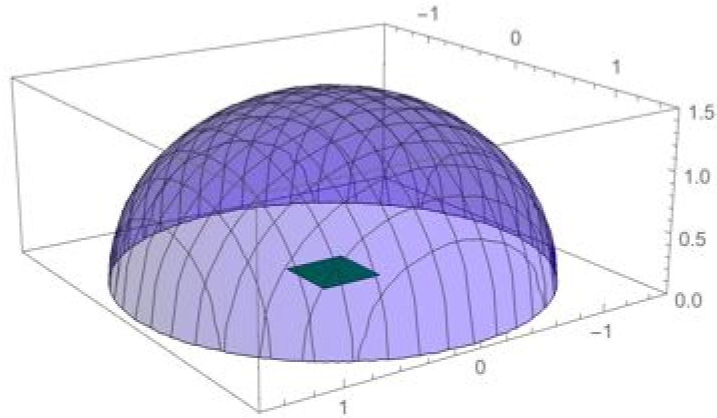


Figure 1: The park (shown in green), is a 450 m by 450 m plane. The hemisphere represents the max range of the drones, and the drones can perform anywhere inside the hemisphere.

According to US law, the vertical distance between the drone and the ground cannot exceed 121.66 m. This diagram is depicted in Figure 2. This means all drone flight would be limited to the volume below the legal height.

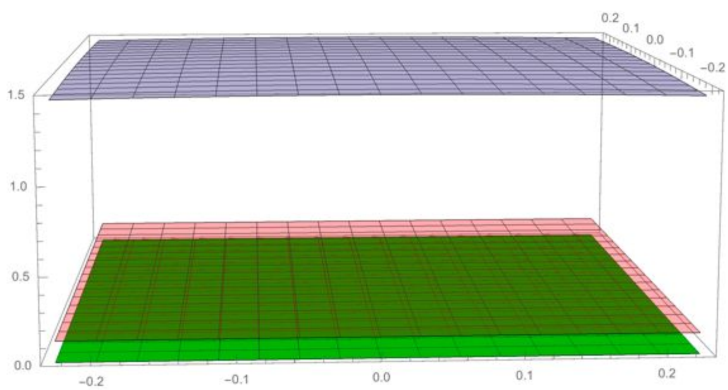


Figure 2: The red plane above shows the maximum legal flying height of the drones (121.66 m). The blue plane represents the max height between the drones and control.

The viewers will be most comfortable by looking up at an angle of 30°. The drones will then need to be on a plane that crosses the maximum height at the same point as the 30° plane. The intersection represents the way to optimize both the viewing of the people and the area of the drone show. This is depicted in Figure 3. Figure 4 represents the optimal plane for flying the drones to further enhance the viewing experience of the spectators.

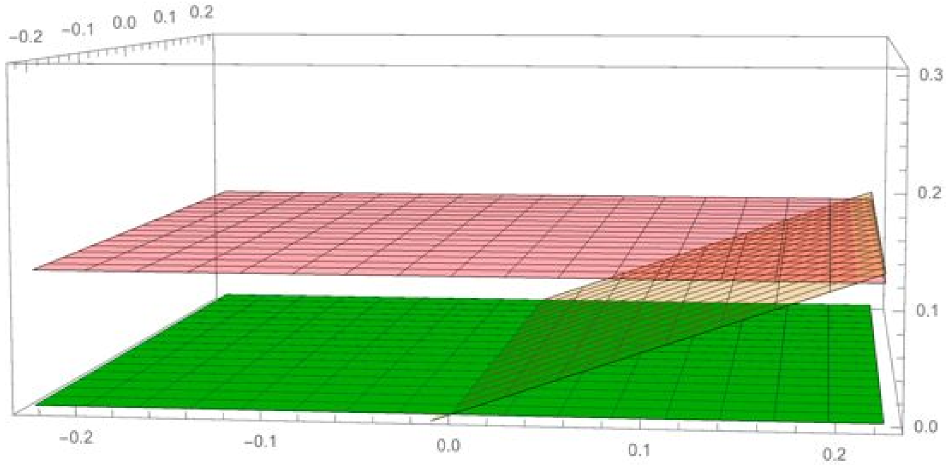


Figure 3: The yellow plane represents the plane of the sight of the viewers half the park away from the viewers half the park away from one side.

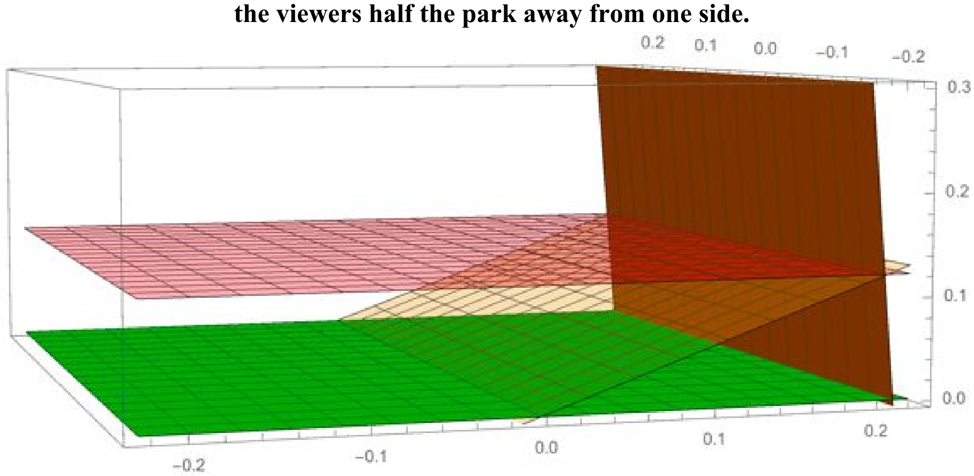


Figure 4: Shows the park, the ideal plane for the people who are viewing, and the plane on which the drones will fly on.

Another consideration for the project is safety. Our project, which proposes making the screen more steep, reduces the area over the park that the drones are flying over. The safety is increased because if no people are under the drones, then no drones can fall on the people. Figure 5 shows the area which would be unsafe in red.

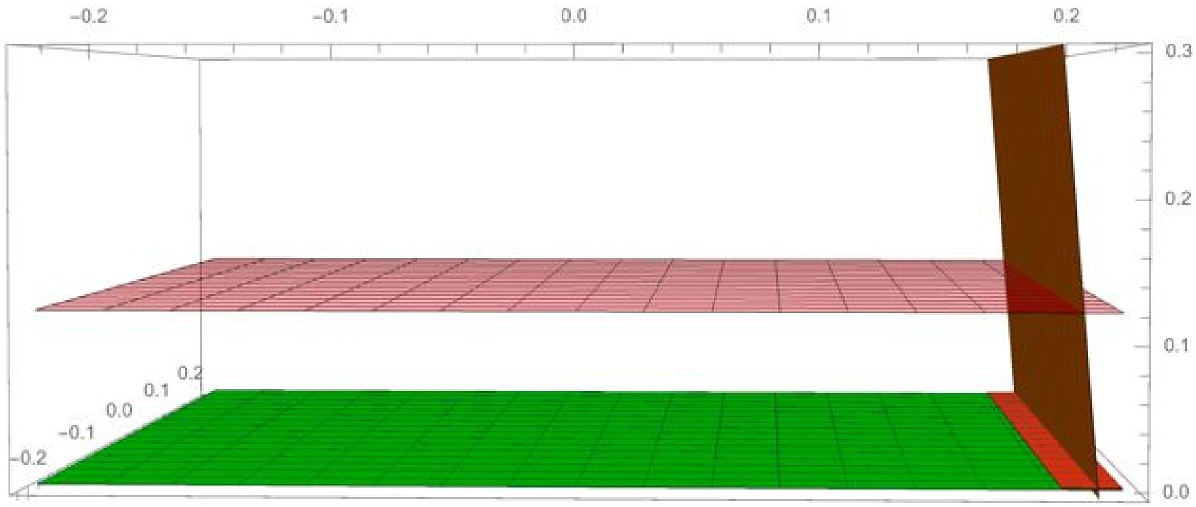


Figure 5: The figure shows the danger zone of the people watching the drones.

The duration of the light show is going to be fifteen minutes. The drones have a battery life of 20 minutes, so fifteen ensures they have enough time to finish the show and land safely. This allows for about four minutes per presentation, leaving the additional time to transition.

The area for the drones based on the approximations above would be about 0.055 km^2. This would leave ample space for the drones to fly around and rearrange themselves to create different images. Also, the danger zone has ample space for the launching of the drones. However, the minimum required area is 0.001215km^2. This leaves seven additional centimeters for launching so that the drones have extra space to launch without being right on top of each other.

It is assumed that on average, the viewers are halfway in the park, and the distance between them to the base of the "viewing plane" is 0.225 km. To calculate the average distance of a drone to a random viewer in the audience, the pythagorean theorem can be used. The distance between the viewing plane and the ground is half of the distance between the pink plane and the ground, which is 60.83 m.

Last year, 500 drones were used in the light show. The optimal drones that should be used for this year's light show can be calculated by looking at each of the images. Since the viewing size is 0.055 km^2, each side of the area is the square root of 0.055 km^2, or 234 m. All of the drones must be at a distance of 5 ft, or 1.524 m apart, according to Intel safety regulations. This means that on a 2-d plane, a total of 154 drones can fit on one side.

The distance between the ground and the max height of a drone (121.66 m), can be calculated using trigonometric functions. The slope of the plane is -20, so the angle between the ground and the viewing plane is 90-tan(20) is 2.87°. The distance between the height and the ground in the viewing plane is 121.66cos(2.87), or 121.5 m. The total area of the plane of the drones is then, 121.5*234, or 28431 m^2. Since the drones can be 1.524 m away from each other, a circle can be created from each of the drones, which have an area of πr^2, or 3896 drones. However, our images only require a maximum of 684 drones to clearly outline the points.

Conclusion:

Weaknesses

The model we have created has a few weaknesses. One weakness is that their needs to be a better analysis of the actual flight paths between the different images. We have successfully handled cross over issues within the actual animations. However, there may be issues between the transformations. Also, the image may need a better look if the weather is poor. Once the weather becomes poor, it will completely throw off the drones, and perhaps lead to crashes.

Analysis

The drone flight would be a great success. The flight would allow for magnificent images to be presented to the public in a way that would inspire. Some people may argue that by using drones there's a threat to public safety. However, if done on a day with safe calm weather, this threat is practically non existent. The structure of the drone presentation allows for the drones to have room to move, but also is small enough that it has a minimal effect on the people that are watching the presentation.

Appendix A:

City Populations (300,000 <= p < = 1,000,000)

Number	City	Population
1	Austin	947890
2	Jacksonville	880,619
3	San Francisco	870,887
4	Columbus	860,090
5	Indianapolis	855,164
6	Fort Worth	854,113
7	Charlotte	842,051
8	Seattle	704,352
9	Denver	693,060
10	El Paso	683,080
11	Washington	681,170
12	Boston	673,184
13	Detroit	672,795
14	Nashville	660,388
15	Memphis	652,717
16	Portland	639,863
17	Oklahoma City	638,367
18	Las Vegas	632,912
19	Louisville	616,261
20	Baltimore	614,664
21	Milwaukee	595,047
22	Albuquerque	559,277
23	Tucson	530,706
24	Fresno	522,053
25	Sacramento	495,234
26	Mesa	484,587
27	Kansas City	481,420
28	Atlanta	472,522

29	Long Beach	470,130
30	Colorado Springs	465,101
31	Raleigh	458,880
32	Miami	453,579
33	Virginia Beach	452,602
34	Omaha	446,970
35	Oakland	420,005
36	Minneapolis	413,651
37	Tulsa	403,090
38	Arlington	392,772
39	New Orleans	391,495
40	Wichita	389,902
41	Cleveland	385,809
42	Tampa	377,165
43	Bakersfield	376,380
44	Aurora	361,710
45	Honolulu	351,792
46	Anaheim	351,043
47	Santa Ana	334,217
48	Corpus Christi	325,733
49	Riverside	324,722
50	Lexington	318,449
51	St. Louis	311,404
52	Stockton	307,072
53	Pittsburgh	303,625
54	Saint Paul	302,398
	Average	531559

List of Coordinates for the Graphs

TRANSLATED		POINTS		ROCKET		POINTS	
Translated	Rocket						
-5.37	0.74	5.50	9.89	0.00	4.89	0.00	-5.55
-4.89	1.00	5.80	9.76	0.30	4.76	1.50	-6.20
-4.49	1.17	6.04	9.56	0.54	4.56	2.70	-7.20
-4.12	1.38	6.13	9.27	0.63	4.27	3.15	-8.65
-3.82	1.49	6.24	8.96	0.74	3.96	3.70	-10.20
-3.52	1.66	6.37	8.67	0.87	3.67	4.35	-11.65
-3.14	1.73	6.44	8.38	0.94	3.38	4.70	-13.10
-2.91	1.98	6.45	8.09	0.95	3.09	4.75	-14.55
-2.72	2.11	6.51	7.82	1.01	2.82	5.05	-15.90
-3.05	2.12	6.58	7.46	1.08	2.46	5.40	-17.70
-3.24	2.20	6.60	7.16	1.10	2.16	5.50	-19.20
-3.51	2.10	6.64	6.77	1.14	1.77	5.70	-21.15
-3.41	2.31	6.66	6.42	1.16	1.42	5.80	-22.90
-3.14	2.48	6.66	6.00	1.16	1.00	5.80	-25.00
-2.87	2.54	6.69	5.53	1.19	0.53	5.95	-27.35
-2.68	2.43	6.66	5.13	1.16	0.13	5.80	-29.35
-2.44	2.31	6.66	4.79	1.16	-0.21	5.80	-31.05
-2.28	2.16	6.62	4.44	1.12	-0.56	5.60	-32.80
-2.15	2.06	6.57	4.10	1.07	-0.90	5.35	-34.50
-2.02	1.93	6.51	3.74	1.01	-1.26	5.05	-36.30
-1.87	1.82	6.44	3.45	0.94	-1.55	4.70	-37.75
-1.75	1.70	6.39	3.17	0.89	-1.83	4.45	-39.15
-1.56	1.56	6.35	2.88	0.85	-2.12	4.25	-40.60
-1.40	1.42	6.26	2.61	0.76	-2.39	3.80	-41.95
-1.20	1.30	6.09	2.36	0.59	-2.64	2.95	-43.20
-0.98	1.24	5.30	1.85	-0.20	-3.15	-1.00	-45.75
-0.81	1.06	5.21	9.79	-0.29	4.79	-1.45	-6.05
-0.60	0.91	5.06	9.54	-0.44	4.54	-2.20	-7.30
-0.39	0.86	4.95	9.29	-0.55	4.29	-2.75	-8.55
-0.21	0.81	4.84	9.01	-0.66	4.01	-3.30	-9.95
0.04	0.78	4.79	8.74	-0.71	3.74	-3.55	-11.30
0.24	0.84	4.68	8.43	-0.82	3.43	-4.10	-12.85
0.40	0.92	4.63	8.11	-0.87	3.11	-4.35	-14.45
0.54	0.96	4.57	7.82	-0.93	2.82	-4.65	-15.90
0.74	1.06	4.52	7.51	-0.98	2.51	-4.90	-17.45
0.90	1.07	4.48	7.22	-1.02	2.22	-5.10	-18.90
1.07	1.04	4.46	6.87	-1.04	1.87	-5.20	-20.65
1.20	1.09	4.43	6.53	-1.07	1.53	-5.35	-22.35
1.35	1.03	4.43	6.24	-1.07	1.24	-5.35	-23.80
1.57	1.07	4.43	5.91	-1.07	0.91	-5.35	-25.45
1.81	1.13	4.43	5.55	-1.07	0.55	-5.35	-27.25
2.05	1.23	4.43	5.24	-1.07	0.24	-5.35	-28.80
2.21	1.27	4.44	4.92	-1.06	-0.08	-5.30	-30.40

2.34	1.27	4.46	4.61	-1.04	-0.39	-5.20	-31.95
-5.76	0.49	4.50	4.30	-1.00	-0.70	-5.00	-33.50
-6.07	0.24	4.54	4.03	-0.96	-0.97	-4.80	-34.85
-6.32	-0.17	4.63	3.76	-0.87	-1.24	-4.35	-36.20
-6.42	-0.58	4.68	3.34	-0.82	-1.66	-4.10	-38.30
-6.46	-0.90	4.77	2.94	-0.73	-2.06	-3.65	-40.30
-6.62	-1.29	4.88	2.65	-0.62	-2.35	-3.10	-41.75
-6.70	-1.67	4.99	2.39	-0.51	-2.61	-2.55	-43.05
-6.80	-1.99	5.10	2.14	-0.40	-2.86	-2.00	-44.30
-6.85	-2.39	5.00	8.00	-0.50	3.00	-2.50	-15.00
-6.76	-2.71	5.28	7.91	-0.22	2.91	-1.10	-15.45
-6.76	-2.96	6.00	8.00	0.50	3.00	2.50	-15.00
-6.63	-3.44	5.62	7.89	0.12	2.89	0.60	-15.55
-6.49	-3.77			-5.50	-5.00	-27.50	-55.00
-6.33	-3.96	4.34	3.79	-1.16	-1.21	-5.80	-36.05
-6.19	-4.20	4.10	3.65	-1.40	-1.35	-7.00	-36.75
-6.02	-4.40	3.88	3.46	-1.62	-1.54	-8.10	-37.70
-5.77	-4.73	3.68	3.23	-1.82	-1.77	-9.10	-38.85
-5.44	-4.78	3.48	3.01	-2.02	-1.99	-10.10	-39.95
-5.19	-4.75	3.36	2.76	-2.14	-2.24	-10.70	-41.20
-4.87	-4.74	3.32	2.47	-2.18	-2.53	-10.90	-42.65
-4.97	-4.59	3.30	2.10	-2.20	-2.90	-11.00	-44.50
-5.13	-4.54	3.37	1.78	-2.13	-3.22	-10.65	-46.10
-5.32	-4.39	3.45	1.51	-2.05	-3.49	-10.25	-47.45
-5.50	-4.25	3.52	1.22	-1.98	-3.78	-9.90	-48.90
-5.67	-4.09	3.61	0.93	-1.89	-4.07	-9.45	-50.35
-5.80	-3.90	3.76	0.69	-1.74	-4.31	-8.70	-51.55
-5.98	-3.72	4.70	2.41	-0.80	-2.59	-4.00	-42.95
-6.11	-3.54	4.43	2.32	-1.07	-2.68	-5.35	-43.40
-6.07	-3.35	4.17	2.14	-1.33	-2.86	-6.65	-44.30
-6.01	-3.02	4.00	2.00	-1.50	-3.00	-7.50	-45.00
-5.85	-2.80	3.97	1.69	-1.53	-3.31	-7.65	-46.55
-5.64	-2.63	3.89	1.42	-1.61	-3.58	-8.05	-47.90
-5.47	-2.52	6.34	2.42	0.84	-2.58	4.20	-42.90
-5.24	-2.43	6.53	2.34	1.03	-2.66	5.15	-43.30
-4.92	-2.51	6.69	2.27	1.19	-2.73	5.95	-43.65
-5.05	-2.46	6.86	2.18	1.36	-2.82	6.80	-44.10
-4.74	-2.24	7.00	2.00	1.50	-3.00	7.50	-45.00
-4.48	-2.08	7.10	1.75	1.60	-3.25	8.00	-46.25
-4.22	-2.01	7.23	1.47	1.73	-3.53	8.65	-47.65
-3.88	-1.97	7.27	1.16	1.77	-3.84	8.85	-49.20
-3.58	-2.06	7.32	0.89	1.82	-4.11	9.10	-50.55
-3.37	-2.10	7.35	0.78	1.85	-4.22	9.25	-51.10
-3.19	-2.21	7.50	1.00	2.00	-4.00	10.00	-50.00
-2.91	-2.26	7.54	1.17	2.04	-3.83	10.20	-49.15
-2.66	-2.40	7.59	1.33	2.09	-3.67	10.45	-48.35
-2.38	-2.60	7.63	1.48	2.13	-3.52	10.65	-47.60

-2.17	-2.75	7.68	1.64	2.18	-3.36	10.90	-46.80
-2.03	-2.91	7.74	1.82	2.24	-3.18	11.20	-45.90
-1.79	-3.08	7.75	1.94	2.25	-3.06	11.25	-45.30
-6.22	-3.16	7.78	2.10	2.28	-2.90	11.40	-44.50
-6.28	-2.95	7.80	2.24	2.30	-2.76	11.50	-43.80
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-6.32	-2.34	7.80	2.56	2.30	-2.44	11.50	-42.20
-6.34	-2.09	7.77	2.66	2.27	-2.34	11.35	-41.70
-6.40	-1.82	7.70	2.88	2.20	-2.12	11.00	-40.60
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-6.00	-0.70	7.10	3.52	1.60	-1.48	8.00	-37.40
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-5.54	-0.09	6.86	3.73	1.36	-1.27	6.80	-36.35
-5.27	0.10	6.56	3.91	1.06	-1.09	5.30	-35.45
-5.06	0.30	6.64	3.87	1.14	-1.13	5.70	-35.65
-4.86	0.43	6.73	3.82	1.23	-1.18	6.15	-35.90
-4.63	0.64	5.61	0.67	0.11	-4.33	0.55	-51.65
-4.38	0.84	5.56	0.81	0.06	-4.19	0.30	-50.95
-4.16	0.97	5.53	0.93	0.03	-4.07	0.15	-50.35
-3.84	1.06	5.50	1.12	0.00	-3.88	0.00	-49.40
-3.59	1.18	5.48	1.31	-0.02	-3.69	-0.10	-48.45
-3.33	1.23	5.43	1.48	-0.07	-3.52	-0.35	-47.60
-3.03	1.34	5.65	0.83	0.15	-4.17	0.75	-50.85
-2.73	1.36	5.67	0.99	0.17	-4.01	0.85	-50.05
-2.41	1.38	5.69	1.16	0.19	-3.84	0.95	-49.20
-2.07	1.22	5.70	1.31	0.20	-3.69	1.00	-48.45
-1.92	1.10	5.71	1.45	0.21	-3.55	1.05	-47.75
-1.72	0.97	5.71	1.57	0.21	-3.43	1.05	-47.15
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-1.28	0.60	5.70	1.65	0.20	-3.35	1.00	-46.75
-1.07	0.39	5.44	1.80	-0.06	-3.20	-0.30	-46.00
-0.85	0.25	5.79	1.88	0.29	-3.12	1.45	-45.60
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-0.06	0.21	6.03	2.12	0.53	-2.88	2.65	-44.40
0.15	0.23	5.20	2.00	-0.30	-3.00	-1.50	-45.00
0.35	0.22	5.73	1.93	0.23	-3.07	1.15	-45.35
0.59	0.30	5.73	1.82	0.23	-3.18	1.15	-45.90
0.94	0.34	5.42	1.94	-0.08	-3.06	-0.40	-45.30
1.18	0.36	5.42	2.05	-0.08	-2.95	-0.40	-44.75
1.47	0.38	5.40	2.20	-0.10	-2.80	-0.50	-44.00
0.07	-0.19	5.73	2.08	0.23	-2.92	1.15	-44.60
-2.56	1.20	5.75	2.18	0.25	-2.82	1.25	-44.10
-2.50	0.71	5.76	2.28	0.26	-2.72	1.30	-43.60
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1.98	-0.33

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5.76	2.51
5.75	2.74
5.76	2.89
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5.66	3.34
5.70	3.60
5.63	2.74
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3.97	-1.83
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3.96	2.86
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4.19	2.94
4.29	2.99
4.41	3.05
4.50	3.12
4.60	3.20
4.70	3.28
4.79	3.30
4.91	3.43
5.00	3.47
5.10	3.55
5.13	3.45
5.06	3.37
5.01	3.32
4.98	3.27
4.93	3.17
4.93	3.07
4.69	-2.23
4.91	-2.22
5.03	-2.27
5.13	-2.39
5.16	-2.51
5.28	-2.64
5.33	-2.80
5.31	-3.02
5.24	-3.17
5.00	-2.50
5.12	-2.70
5.49	0.38

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